Long Term Effects of Partner Programming in an Introductory Computer Science Sequence

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ASEE'16
Pair Programming

• A software development technique
• Two programmers + one workstation
• Higher student performance in introductory computer science courses
Pair Programming

• Higher project scores and similar exam scores
  – McDowell et al.

• Higher student retention rates in first year computing courses
  – Nagappan et al. and McDowell et al.
Pair Programming + Demographics

- Other research has examined its impact on different demographic groups
- Higher programming skills for students with lower SAT scores
  - Braught et al.
- Higher performance especially for students who begin with low confidence levels
  - Wood et al.
Pair Programming in Industry

• Researchers have also extensively examined pair programming and its effects in industry

• Higher-quality programs with quicker time-to-market
  – Williams et al. (2000) and Cockburn et al. (2001)
Pair Programming Concerns

What the CTO expects

Careful, your loop can throw an Exception because of your type constraint!

Indeed, thanks!

What usually happens

Oh hey, try this one! "9gag crazy cat"

No, wait, this one is hilarious, look!

Comic: https://developer.atlassian.com/blog/2015/05/try-pair-programming/
Pair Programming Concerns

• Students may divide the work instead of working together, missing some material

• Students may become dependent on partnerships, leading to future difficulty working independently

• Key question: what happens in future courses?
Research Questions

• Are student partnerships during a past semester associated with changes in student performance during a future semester while working alone?

• Do observations about student partnerships vary with different demographic groups?
Our Data Set

- Large research university
- 2,234 total students
- Consecutive courses
- Data set included:
  - Project scores
  - Exam scores
  - Partner status in CS2
  - Gender
  - Cumulative GPA
Our Data Set

- 4 semesters of CS2
- 2 semesters of CS3
- Consistent curriculum across semesters
Description of CS2

- Audience: prospective CS majors and minors
- Covers programming and intro data structures
- 2 exams, 5 projects
- Students have the option to partner on projects 2-5
Description of CS3

- Audience: prospective CS majors and minors
- Covers data structures and algorithms
- 2 exams, 4 projects
- Students must work alone on all projects

CS1

CS2

CS3

Advanced Courses

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Methods

• Compared sample means
• Statistical significance using student's t-test
• Partnership status: two subsets
  – Partnered, alone
• Gender groups: two subsets
  – Men, women
• GPA groups: four subsets
  – By quartile
Outline

• Introduction
• Methods and data set
• CS2 results
• CS3 results
• Discussion and conclusions
### Effects on CS2 general population

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Partnered Mean (N)</th>
<th>Alone Mean (N)</th>
<th>Difference</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects</td>
<td>83.3% (632)</td>
<td>80.0% (393)</td>
<td>3.3%</td>
<td>0.0001</td>
</tr>
<tr>
<td>Exams</td>
<td>71.8% (632)</td>
<td>74.6% (393)</td>
<td>-2.8%</td>
<td>0.001</td>
</tr>
</tbody>
</table>

#### Overall CS2 Performance

- **CS2 Project Scores**
- **CS2 Exam Scores**

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Effects on CS2 general population

• Students who partnered tended to score better on projects
  – Consistent with the literature in Pair Programming

• Exam scores were lower when students choose to partner on projects in CS2
  – Several factors could influence this observation. For example, the instructors did not control team selection.
## Effects on CS2 by Gender

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Gender</th>
<th>Partnered Mean (N)</th>
<th>Alone Mean (N)</th>
<th>Difference</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects</td>
<td>Men</td>
<td>83.0% (473)</td>
<td>80.3% (305)</td>
<td>2.7%</td>
<td>0.005</td>
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<tr>
<td></td>
<td>Women</td>
<td>84.1% (178)</td>
<td>79.1% (88)</td>
<td>5.0%</td>
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<tr>
<td>Exams</td>
<td>Men</td>
<td>72.0% (473)</td>
<td>75.2% (305)</td>
<td>-3.2%</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>70.9% (178)</td>
<td>72.5% (88)</td>
<td>-1.6%</td>
<td>0.388</td>
</tr>
</tbody>
</table>

### Overall CS2 Performance by Gender

#### CS2 Project Scores by Gender

#### CS2 Exam Scores by Gender
Effects on CS2 by Gender

• Women had nearly double the benefit on projects of CS2 partnerships compared to men
  – Results consistent with the literature
  – Partnerships can be particularly beneficial to women in introductory computer science courses
## Effects on CS2 by GPA

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Quartile</th>
<th>Partnered Mean (N)</th>
<th>Alone Mean (N)</th>
<th>Difference</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects</td>
<td>1st</td>
<td>76.6% (146)</td>
<td>67.8% (104)</td>
<td>8.8%</td>
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<td></td>
<td>2nd</td>
<td>81.4% (179)</td>
<td>77.7% (86)</td>
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<td>0.033</td>
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<td></td>
<td>3rd</td>
<td>85.7% (154)</td>
<td>83.6% (98)</td>
<td>2.1%</td>
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<tr>
<td></td>
<td>4th</td>
<td>89.5% (153)</td>
<td>90.6% (105)</td>
<td>-1.2%</td>
<td>0.095</td>
</tr>
<tr>
<td>Exams</td>
<td>1st</td>
<td>61.6% (146)</td>
<td>62.9% (104)</td>
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<td>0.434</td>
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<tr>
<td></td>
<td>2nd</td>
<td>66.9% (179)</td>
<td>70.2% (86)</td>
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<td>0.031</td>
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<tr>
<td></td>
<td>3rd</td>
<td>74.4% (154)</td>
<td>78.2% (98)</td>
<td>-3.8%</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>4th</td>
<td>84.5% (153)</td>
<td>86.4% (105)</td>
<td>-1.9%</td>
<td>0.037</td>
</tr>
</tbody>
</table>
Effects on CS2 by GPA

- We see that the associated benefit of partnerships for project scores increases with lower GPA

Overall CS2 Projects scores by GPA

Overall CS2 Exam scores by GPA
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### Effects on CS3

<table>
<thead>
<tr>
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<th>Alone Mean (N)</th>
<th>Difference</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Projects</td>
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<tr>
<td>Exams</td>
<td>62.7% (312)</td>
<td>64.6% (195)</td>
<td>-1.9%</td>
<td>0.153</td>
</tr>
</tbody>
</table>

Overall CS3 Performance

- We could not make any statistically significant conclusions when looking at the impact of partnerships in CS2 on performance in CS3 within the general population.
## Effects on CS3 by Gender

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<th>Alone Mean (N)</th>
<th>Difference</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects</td>
<td>Men</td>
<td>77.2% (244)</td>
<td>72.6% (155)</td>
<td>4.6%</td>
<td>0.023</td>
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<tr>
<td></td>
<td>Women</td>
<td>76.7% (67)</td>
<td>69.3% (40)</td>
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<td>0.111</td>
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<tr>
<td>Exams</td>
<td>Men</td>
<td>62.9% (244)</td>
<td>64.6% (155)</td>
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<td>0.110</td>
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<td>Women</td>
<td>61.9% (67)</td>
<td>60.9% (40)</td>
<td>1.0%</td>
<td>0.712</td>
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</tbody>
</table>

**Overall CS3 Performance by Gender**

![CS3 Projects Scores by Gender](image)
Effects on CS3 by Gender

• Men who partnered in CS2 had a higher average project score in CS3 higher than those who had worked alone

• Other results were not statistically significant
## Effects on CS3 by GPA

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</thead>
<tbody>
<tr>
<td>Projects</td>
<td>1st</td>
<td>60.4% (88)</td>
<td>51.2% (39)</td>
<td>9.2%</td>
<td>0.032</td>
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<tr>
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<td>71.0% (75)</td>
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<tr>
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<td>3rd</td>
<td>81.7% (78)</td>
<td>77.7% (48)</td>
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<tr>
<td></td>
<td>4th</td>
<td>90.8% (71)</td>
<td>92.1% (56)</td>
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<tr>
<td>Exams</td>
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<tr>
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<td>64.4% (78)</td>
<td>66.6% (48)</td>
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<td>0.223</td>
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<tr>
<td></td>
<td>4th</td>
<td>72.0% (71)</td>
<td>75.8% (56)</td>
<td>-3.8%</td>
<td>0.008</td>
</tr>
</tbody>
</table>
Effects on CS3 by GPA

• Lowest GPA quartile associated with higher project scores in CS3 after partnering in CS2
• Highest GPA quartile associated with lower exam scores in CS3 after partnering in CS2
Outline

• Introduction
• Methods and data set
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Discussion

• Partnerships were mostly associated with increased project performance in both CS2 and CS3; especially among those in the lowest GPA quartile

• Working alone was mostly associated with higher exam scores in both CS2 and CS3; especially among those in the highest GPA quartile
Limitations

• Students had the choice to partner on projects in their CS2 course
  – Also had choice of partner
• We had did not have control over group dynamics
Conclusions

• Replicated prior work in pair programming during the same semester

• Both gender groups were associated with benefits from CS2 partnerships
  – Women more than men

• Students with lower GPAs were associated with the most benefits from partnering
Conclusions

• Association between students in the lowest GPA quartile and higher CS3 project scores when partnering
• Did not observe any evidence of students performing poorly as a results of partnering